Open Access

J. Glob. Innov. Agric. Sci., 2024, 12(1):255-261
ISSN (Online): 2788-4546; ISSN (Print):2788-4538
DOI: https://doi.org/10.22194/JGIAS/24.1276
http://www.jgiass.com

Society for Innovative Agiculture

Assessing the economic viability of renewable energy systems in agriculture: a comprehensive review

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The economics of renewable energy sources are very important factors to encourage its use in the short and long run. The most important economic factor is associated with the initial investment cost of renewable energy systems. Despite their significance, operational costs do not primarily drive the decision to adopt specific renewable energy systems. The objective of this review is to investigate the economics of renewable energy systems in the agricultural sector concerning the initiative investment cost, the operational cost, and the economic returns of these systems. The results showed that the initiative investment cost in the solar energy systems was the cheapest compared to the systems. This fact contributed to the high distribution of these systems in agricultural activities. The operational cost of the other systems including the wind, geothermal, and bioenergy systems were lower than the solar energy system, but still, their use in agricultural activities was for specific purposes. The economic returns of various renewable energy systems depend on their intended use and the nature of agricultural activities.

Keywords: Agricultural activities, renewable energy sources, Initiative investment cost, OC, Economic returns**.**

INTRODUCTION

The usage trends of renewable energy sources (RES) increased over time. According to IRENA (2023), the use of RES sources has been doubled from 2010 to 2022. The high trends of RES usage were recorded mostly for the wind energy (WE) and solar energy (SE). The distribution of RES especially the SE and WE resources was widely developed in Asia compared to Africa. In the Middle East, the distribution of SE use as RES was very wide compared to the WE source. Moreover, the use of SE in the Middle East is more widespread than in other regions. This is associated with the type of weather that facilitates the use of these sources.

The RES form original and sustainable energy sources in the agricultural sector. Majeed *et al.* (2023) reported that the RES can be used in the agricultural sector creating a wide range of alternatives that meet the different geographical areas and the economic conditions of different areas. The RES can help executing different agricultural activities mainly facilitate harvesting in distant areas. The type of RES is restricted to the type of environment dominated in different areas. On the other hand, the adoption of RES will facilitate the preservation of the environment through the alleviation of the emission of pollution gases. Moreover, the feasibility of agricultural activities will be affected directly to the saving made in the cost of energy. Moreover, Gangil and Mehta (2022) and Bekir (2018) reported that the RES will affect the agricultural production processes in the intermediate and long-run activities.

Alsagr and van Hemmen, (2021) and Candra *et al.* (2023) reported that the use of RES is highly connected to economic constraints in different areas of the world and the area suitability to use any type of RES. Painuly and Wohlgemuth (2019) found that the financial constraint forms the major one faces the transfer of RES in the agricultural sector. Timmons (2017) found that the other constraints are related to the financial aids by the government support and the regulations controlling the adoption of RES. The impact of economic constraints varies between developed and developing countries.

MATERIALS AND METHODS

The objective of this reviewing paper is to investigate the economic factors that affect the use of RES in the agricultural sector in different areas. Literature was used to collect the secondary data for analysis. The paper concentrated on studies measured the economic feasibility of using the RES in

Al-Dalaeen, J.A. 2024. Assessing the economic viability of renewable energy systems in agriculture: a comprehensive review. Journal of Global Innovations in Agricultural Sciences 12:255-261.
[Received 17 Jan 2024; Accepted 26 Feb 2024; Published 16 Mar 2024]

agricultural activities. The literature from Jan 2015 to Dec. 2023 was collected and analyzed to make the different facts related to the use of RES in the agricultural sector. Different databases were used for literature collection mainly the Google Scholars. The search terms included RES, agricultural sector, initiative investment cost (IIC), operational cost (OC), energy independence (EI), long-term savings (LTS), diversification of income streams (DOIS), and resilience to climate change (RTCC). The previous terms formed the main topics for the results of this review. This review exclusively considered studies published online in English.

RESULTS AND DISCUSSION

The results will investigate the different economic constraints of using RES in the agricultural sector in different regions. The constraints related to IIC, OC, EI, LTS, DOIS, and resilience to climate change will form the titles of the results.
***Initial investment cost*:** The adoption of RES in the agricultural sector is significantly affected by the initial cost. Yigezu *et al.* (2018) reported that the smallholders showed low attendance to adopt technologies (TC) of RES with IIC. On the other hand, Ali *et al.* (2023) showed that the access to free costly agricultural TC including the adoption of these TCs increases and zero-tillage seeders increased. On the other side, a very important factor related to the connection between the annual returns and the input of the adoption of RES forms a constraint for the adoption of RES. Different researches have shown that the adoption of RES TC increases when the initial cost decreased. Bilal and Barkmann (2019) found that the adoption of RES will increase if the quality of production and production alternatives will increase. Cumming *et al.* (2020 and Liontakis, *et al.* (2021) found that its urgent to encourage the adoption of RES through providing the RES TC with a reasonable initial cost or provide it with no cost to increase its use in large-scale among farmers.
The literature has shown that four RES are most commonly used in agriculture activities including WE, geothermal (GE), SE and bioenergy (BE). Bekir (2018) and Elkadeem *et al.* (2019) found that the lowest initial cost was recorded for SE, followed by BE, then WE, and the last one was for GE. The previous RES considered suitable sources for the agricultural sector. The SE is known to be used for different purposes including drying plants, heating homes and greenhouses, and power water pumping. Other sources such as BE can be used for heating, electricity production, and fuel production. Also, WE can be used for the generation of electricity that can be used for different agricultural activities.
***SE*:** The lowest initial cost of SE as RES justifies its wide distribution and use in the agricultural sector for different purposes. IRENA (2023) has shown that the production of electricity through SE as RES has increased from 41,577 MW in 2010 to 1,061,674 MW in 2022 with an increase reaching 2,453%. The second initial cost of electricity production using WE as a RES justifies, its wide distribution and the increase of electricity production from 181,090 MW in 2010 to 898,856 MW in 2022. Sharan *et al.* (2021) found that the SE initial cost is very low compared to the GE. Yusupov (2021) has shown that the high cost of GE results from the cost of drilling GE wells. The results showed that the combination of both SE and GE would reduce the initial cost.
***BE*:** The initial cost of BE sources compared to SE varies depending on the specific TC and scale of the system. Gutierrez *et al.* (2022) found that the inclusion of a concentrated SE (CSP) block in a thermochemical biorefinery (TBRF) increased investment costs by up to 74% compared to a stand-alone TBRF. Boujjat *et al.* (2021) assessed the economic feasibility of a solar gasification process and found that the minimum hydrogen production cost for SE-only and hybrid gasification processes was higher than that of conventional autothermal biomass gasification. Bai *et al.* (2017) developed a SE-BE hybrid power generation system and reported that the levelized cost of energy was reduced compared to typical BE power systems. Khalid *et al.* (2017) and Bai *et al.*, (2017) presented a multigeneration system using SE and BE. They found that the hybrid system was more efficient and economical compared to individual SE and BE systems. Bautista-Peñuelas *et al.* (2023) simulated a hydrothermal liquefaction (HTL) SE plant and found that the minimum selling price of bio-oil was estimated between 1.27 and 1.55/kg.
***WE*:** The initial cost of WE sources is generally lower compared to SE sources. In the context of RES, Mohammed *et al.* (2019) found that the net cost of installing a 3KW wind turbine (WT) system was about 7,340.00 USD, while the net cost of installing a 3 KW SE system was about 14,792.00 USD. Klockl *et al.* (2023) compared different stand-alone PV WT energy systems and found that the levelized cost of energy for a SE/WE/battery/hydrogen system was 0.65 USD/kWh, while the levelized cost of energy for a WE/battery system was 3.17 USD/kWh. Additionally, Hassan (2021) studied desalination systems powered by RES and found that the cost of one cubic meter of purified water using a SEPV system was 0.08, while the cost of using WT systems was 0.19. These findings suggest that WE sources generally have a lower initial cost compared to SE.
***OC*:** Babu *et al.* (2021) and Saputra and Umar (2021) found that the determinants of the OC of RES in agriculture resulted from different factors represented in extent of fuel and electricity consumption, the internet availability, the environmental practices, total value of production, and the acre value. Moreover, Fallahinejad *et al.* (2022) found that the system size is influenced by the total value of production and acre value, while, on the other side, TC adoption is influenced by environmental practices, internet connection, and electricity price. Fuchs *et al.* (2022) found that the OC of RES can be affected by fluctuations in electricity consumption throughout the day and the season. Additionally,

Bhattacharyya *et al.* (2022) found that the overall OC of the system is influenced by the cost of producing synthetic fuels for outdoor work may impact. In conclusion, the OC of RES can be decreased through economies of scale, rising prices of fossil fuels and advancements in TC.

The OC of BE systems compared to SE systems in agriculture varies depending on the specific case study. Gil *et al.* (2021) found that the Levelized Cost of Heat (LCOH) values for a SE and BE boiler were 0.045 and 0.099 USD/kWh respectively, indicating that the solar field had a lower OC. Villaroel-Schneider *et al.* (2023) found that the aggregated cost of producing electricity and heat in a poly-generation plant ranged from 0.044 to 0.070 USD/kWh, with the penetration of SE reaching up to 32%. Additionally, a RES that included BE and SE TCs achieved financial savings and reductions in fossil fuel and CO_2 emissions, suggesting its viability and sustainability *(Forbes et al. 2016)*. While the specific cost comparison between BE and SE systems is not explicitly mentioned in Achour and Zejli 2018 and Bai *et al.* (2017), they do highlight the potential of SE based solutions for heating in agricultural environments.

Anifantis *et al.* (2019) and Goel and Sharma (2021) found that GE systems have been found to have lower OC compared to SE systems in agriculture. Kurpaska *et al.* (2021) compared the energy demand costs of different heating systems for a greenhouse, it was found that a closed-loop ground source heat pump (GWHP) system had significantly lower costs compared to fuel oil and natural gas systems. The GWHP system resulted in cost savings of 67% and 53% respectively. Additionally, Giusti *et al.*, (2022) found that the use of SE for water pumping for irrigation was found to be economically viable compared to diesel pump sets . The OC for the use of SE in water pumping was lower than that of a diesel pump set. These findings suggest that GE systems offer cost advantages over SE systems in the agricultural sector.

The OC of WE compared to SE systems in agriculture varies depending on the specific context. Goel and Sharma (2021) discussed the cost-effectiveness of small-scale WE or SE powered irrigation systems, suggesting that a SE photovoltaic (SEPV) array was a better match for irrigation energy requirements than a WT alone. However, Junedi *et al.* (2022) found that SEPV systems were shown to be more expensive than small WT systems for large-scale irrigation in the Great Plains. In a hybrid RES (HRES) comprising a diesel generator, battery TCs, WT, and PV, Elkadeem *et al.* (2019) found that the hybrid RES to be a feasible solution for supplying power to an agriculture-isolated area, with a minimum cost of energy. Overall, the OC comparison between WE and SE systems in agriculture depends on factors such as scale, location, and specific energy requirements. In Jordan, the use of SE as RES is very high compared to other RESs as the initial cost of a SE system (SRS) is lower than other systems (IRENA 2023). This made the distribution of SRS very wide compared to other systems in the last years.

***Economic returns (ER)*:** The ER of RES depend on the possibility of using the source in different agricultural activities, the savings made by using RES, and the OC of the system. Comparing the returns of SE systems to WE, SE are economically viable for agricultural irrigation. Biberci (2023) studied a techno-economic analysis of a grid-connected SEPV system in Turkey which showed an asset return of 9.14% and a depreciation period of 8.7 years. Moreover, Junedi *et al.* (2022) compared different configurations of integrated SEPV systems and found that ground-mounted PV farms (GMPV) had the lowest levelized cost of energy (LCOE) with a range of 0.04−0.13/kWh . Kose *et al.* (2018) found that renewable hybrid power generation system consisting of PV panels and WT was found to save $10,410 on energy in twenty years. However, the information related to the comparison of the ER of WE systems to SE systems in agriculture is missing.

GE systems have been found to have economic feasibility and profitability in agriculture. A study by Calise *et al.* (2020) compared two renewable poly-generation plants and found that GE systems had a lower payback period compared to SE

Table 1. Summary of findings

Constraints	SE	WE	BE	GE
Adoption	High	High	Moderate	Moderate
Geographic location	High tendency of use and prominent in sunny areas like Jordan	High tendency of use in windy areas like Jordan	Not connected to geography	Not connected to geography
IIC	Lowest IIC	Moderate	Expensive	Expensive
OC	High	Moderate	Moderate	Moderate
ER	Viable for water pumping, can be used in mixed RES systems	Viable in mixed RES systems	Effective for heating uses, viable in mix RES systems	Viable in mix RES systems
Farm size	The cost-effectiveness of RES is influenced by the scale and nature of agricultural operations.	The cost-effectiveness of RES is influenced by the scale and nature of agricultural operations.	The cost-effectiveness of RES is influenced by the scale and nature of agricultural operations.	The cost-effectiveness of RES is influenced by the scale and nature of agricultural operations.
TC availability	Relied completely on technology availability	Relied completely on technology availability	Relied on technology and the inputs for energy production	Relied on technology and the inputs for energy production

systems. Also, Calise *et al.* (2018) analyzed a renewable poly-generation system and found that the GE configuration provided the highest economical profitability with a lower simple payback time. These findings suggest that GE systems offer ER and profitability in agriculture compared to SE systems.

The BE and SE systems in agriculture have been compared in terms of their ER. Geoghegan and O'Donoghue (2023) showed that the market return from growing BE feedstocks such as grass silage and willow biomass is less than the average agricultural income from traditional farming systems in Ireland. On the other hand, Bowman *et al.* (2023) reported that when the social value of the feedstock is considered by putting a monetary value on displaced greenhouse gas (GHG) emissions, BE production can provide a better return to farmers than cattle and sheep farming. On the other hand, Biberci (2023) found that the market and social returns are higher for using land to erect SEPV arrays than any of the main agricultural activities in Ireland. In Switzerland, Seo *et al.* (2022) reported that the technical agricultural resources potential for SEPV and biomass is estimated to be significant, with the possibility of fostering complementarity in the system if resources are pooled within the agricultural setting. In Laaroussi and Bouayad (2019) showed that a techno-economic analysis of a grid-connected SEPV system for agricultural irrigation showed that it is technically and economically appropriate, with an asset return of 9.14% and a depreciation period of 8.7 years . In the case of integrated biomass gasification and SE systems, the SE-assisted biomass process showed higher economic feasibility than the biomass-only process, with additional annual income from carbon credit pricing acting as an important influencing factor. In Morocco, Mergoul *et al.* (2018) found that SEPV pumping irrigation was found to have a good return on investment and a better price/quality ratio compared to conventional pumping systems, contributing to energy cost reduction and environmental preservation. Table 2 summarizes the findings of the RES.

***Conclusions and Recommendations*:** The objective of this reviewing paper is to investigate the economics of RES use in the agricultural sector. The results showed that four types of RES are used including SE, WE, GE and BE. In the past years, the concentration was on GE and BE sources such as RESs. Interest and attention were given to other sources including SE and WE. This appeared through the high increase in the internal generation of electricity produced using these two sources. The geographical location was found to play a crucial role in the RES that can be adopted. In areas with high sunny days over the year, the adoption and preference of SE as a RES was higher. Even though, the geographical places that facilitate the use of WE increased the adoption of these sources in the previous years. The reliability of WE was found to occupy the second place after the SE globally. In some countries, like Jordan, the adoption of SE systems was very high in the last ten years forming a reliable source of RES that can be used in agricultural activities.

The economic directions form the determinants of the selectivity of the proper RES to use in agriculture, especially in the absence of governmental support. The farmers in agribusiness care for the savings resulting from the RES in different stages of its use including the initial, operating costs and the returns of using these sources. The other concerns related to environmental protection are mainly the government concerns which should be given attention to improve through the support introduced for farmers to use RES. The size of agribusiness on the other side effects the attitudes to adopt the RES as the cost and returns of RES change dramatically according to the farm size and the diversity of activities practiced within the farm. On the other hand, the availability of TC and its distribution will affect the adoption of RES through the effect of demand and supply for these systems.

Concerning the initial construction cost, the results showed that the SE had the lowest IIC compared to other systems. WE was found to have the second IIC compared to GE and BE systems. The high cost of the GE and BE systems was a result of the expensive infrastructure needed to construct these two types of systems. The wide distribution of SE systems may contribute to a decrease in the price of the IIC compared to other systems. On the other hand, the OC was found to be higher in SE systems compared to other systems WE, GE, and BE systems. The high OC of SE was found to affect the economics of using SE compared to other systems.

The studies have shown that the ER of RES varied from one system to another and the purposes of using these systems in agricultural activities. In some studies, SE was more feasible in the case of its use for water pumping, while in other cases a mix of RES produced more feasible results in the agribusiness. In general, despite the high operating costs of SE systems, still it can be reliable for use in agricultural activities. The other systems were found to be feasible in agricultural practices over time as the operation costs of these systems are low including the GE and BE systems. The review recommends that the government's role is very important to improve the feasibility of the RES by encouraging the availability of the TC and equipment needed for the infrastructure and in other conditions to introduce financial aids to encourage the use of the most suitable systems compatible with the area geography.

Other factors may affect the economics of RES and encourage the use RES in agricultural activities. These factors related to the governmental support through introducing incentives such as environment, tariffs and taxes incentives which increase RES feasibility. Al-Dalaeen (2024) has shown that the governmental support increased the attitudes of adopting the RES in agricultural sector. The government introduction of advanced TC increases the efficiency of using RES in agriculture through improving the feasibility. Increasing the

farmers awareness and understanding of RES improves the type of RES adoption and improves the feasibility. The introduction of TC and the improvement of infrastructure will contribute to increase the economic feasibility to use RES in agricultural activities.

The customization of different solutions to cover different agricultural needs will improve the efficiency of RES production and use in agricultural activities. These efforts can be achieved with the cooperation between the public and private sectors. The continuous development of the tools used in utilizing the RES and adoption of proper TC according to the geographical suitability will increase the economic viability of these systems and encourage its distribution.

***Future Research*:** The future research should concentrate on the areas that increase the adoption of RES such as the effect of training for RES on improving the economic feasibility in agricultural sector.

***Authors' contributions*:** Jawad Atef Al-Dalaeen completed this work himself including data collection, analysis, and writing the paper.

***Funding*:** This work is funded by the author himself

***Ethical statement*:** This paper is based on reviewing published literature, so ethical statement is not applied

***Availability of data and material*:** I declare that the submitted manuscript is my work, which has not been published before and is not currently being considered for publication elsewhere?

***Acknowledgement*:** I thank your journal for publishing my paper**.**

Code Availability: Not applicable

***Consent to participate*:** Not applicable

***Consent for publication*:** I submitted consent to publish this research article in JGIAS

REFERENCES

Achour, Y. and D. Zejli. 2018. A thermo-economic analysis of solar energy-based heating systems for greenhouse application. Proceedings of 2018 6th International Renewable and Sustainable Energy Conference, IRSEC 2018 1–6.

Al-Dalaeen, J. 2024. The economic constraints of adopting renewable energy in farming systems. Journal of Global Innovations in Agricultural Sciences 11:534–541.

Ali, E.H., D.A. Abu Duaila, and M.K. Mohammed. 2023. a Study of Economic, Social, and Institutional Factors Affecting the Adoption of the High-Rank Wheat Seeds. Iraqi Journal of Agricultural Sciences 54:161-175.

Alsagr, N., and S. van Hemmen. 2021. The impact of financial development and geopolitical risk on renewable energy consumption: evidence from emerging markets. Environmental Science and Pollution Research 28:25906-25919.

Anifantis, A.S., E. Lorencowicz, A. Przywara, S. Pascuzzi, G. Ruggiero and F. Santoro. 2019. Common greenhouse conditioning plants compared with versatile geothermal system in Ames, Iowa. Engineering for Rural Development 18:1325-1330.

Babu, R., S. Raj and B.R.V. Prasad. 2021. A Review at the Utilization of Renewable Energy in an Agricultural Operation. Biophysical Economics and Sustainability 6:1-13.

Bai, Z., Q. Liu, J. Lei, X. Wang, J. Sun and H. Jin. 2017. Thermodynamic evaluation of a novel solar-biomass hybrid power generation system. Energy Conversion and Management 142: 296-306.

Bautista-Penuelas, Eduardo Macías, J.D., H.I.´ Villafan-Vidales, P.J. Valades-Pelayo, P. Arcelus-Arrillaga, A. Ayala-Cortes, K. Cedano-Villavicencio, C.A. Arancibia-Bulnes and M.I. Pena-Cruz. 2023. Hydrothermal liquefaction of wood wastes in a concentrating solar plant : A techno-economic analysis. Energy Conversion and Management 282:1-10.

Bekir, Y. 2018. Use of renewable energy resources in agriculture the case of Turkey. African Journal of Agricultural Research 13:2037-2054.

Bhattacharyya, P., P. Santra, D. Mandal and B. Mondal. 2022. Pricing of Renewable Energy-Based Applications in Agriculture. Pages 83–108 *in* Pricing of Ecosystem Services in Agriculture: A Basis of Crop Insurance.

Biberci, M.A. 2023. Techno-economic analysis of a solar-powered agricultural irrigation system using PV*Sol software: A case study in Konya. International Journal of Agriculture Environment and Food Sciences 7:156-162.

Bilal, M., and J. Barkmann. 2019. Farm and farmer capital foster adoption of improved quality agrochemical inputs in the cotton-wheat zone of the Punjab, Pakistan. Journal of Agriculture and Rural Development in the Tropics and Subtropics 120:229-240.

Boujjat, H., S. Rodat, and S. Abanades. 2021. Techno-economic assessment of solar-driven steam gasification of biomass for large-scale hydrogen production. Processes 9:1-20.

Bowman, G., T. Huber and V. Burg. 2023. Linking Solar and Biomass Resources to Generate Renewable Energy: Can We Find Local Complementarities in the Agricultural Setting? Energies 16:2-17.

Calise, F., A. Macaluso, A. Piacentino and L. Vanoli. 2018. Energy Management in Geothermal Energy Systems. Comprehensive Energy Systems 5:742-777.

Calise, F., F.L. Cappiello, M.D. D'Accadia and M. Vicidomini. 2020. Thermo-economic analysis of hybrid solar-geothermal polygeneration plants in different configurations. Energies 13:2-29.

Candra, O., A. Chammam, J.R.N. Alvarez, I. Muda and H. Aybar. 2023. The Impact of Renewable Energy Sources on the Sustainable Development of the Economy and

Greenhouse Gas Emissions. Sustainability (Switzerland) 15:2-11.

Cumming, D., S. Johan, C. Oberst and I. Uzuegbunam. 2020. The unintended consequences of biotechnology innovation adoption. Industry and Innovation 27:1089-1109.

Elkadeem, M.R., S. Wang, E.G. Atia, M.B. Shafik, S.W. Sharshir, Z. Ullah and H. Chen. 2019. Techno-economic Design and Assessment of Grid-Isolated Hybrid Renewable Energy System for Agriculture Sector. Proceedings of the 14th IEEE Conference on Industrial Electronics and Applications, ICIEA 2019 1562-1568.

Fallahinejad, S., M. Armin and M.R. Asgharipour. 2022. The effect of farm size on the sustainability of wheat production using emergy approach. Current Research in Environmental Sustainability 4.

Forbes, E.G.A., R.J. Olave, C.R. Johnston, J.D. Browne and J. Relf. 2016. Biomass and bio-energy utilisation in a farm-based combined heat and power facility. Biomass and Bioenergy 89:172-183.

Fuchs, C., D. Meyer and A. Poehls. 2022. Production and Economic Assessment of Synthetic Fuels in Agriculture-A Case Study from Northern Germany. Energies 15:2-21.

Gangil, S., and C. Mehta. 2022. Application of Renewable Energy in Indian agriculture. Journal of Rice Research 15:146-156.

Geoghegan, C., and C. O'Donoghue. 2023. An analysis of the social and private return to land use change from agriculture to renewable energy production in Ireland. Journal of Cleaner Production 385:1-26.

Gil, J.D., J. Ramos-Teodoro, J.A. Romero-Ramos, R. Escobar, J.M. Cardemil, C. Giagnocavo and M. Pérez. 2021. Demand-side optimal sizing of a solar energy–biomass hybrid system for isolated greenhouse environments: Methodology and application example. Energies 14: 1-22.

Giusti, E., L. Ciappi, P. Ungar, C. Zuffi, D. Fiaschi, G. Manfrida and L. Talluri. 2022. Exergo-economic and exergo-environmental analysis of a binary geothermal power plant with solar boosting. Journal of Physics: Conference Series 2385:1-12.

Goel, S., and R. Sharma. 2021. Economic Analysis of Solar Water Pumping System for Irrigation. Lecture Notes in Networks and Systems 151: 157–167.

Gutiérrez, R.E., K. Guerra and P. Haro. 2022. Exploring the techno-economic feasibility of new bioeconomy concepts: Solar-assisted thermochemical biorefineries. Applied Energy 322:1-19.

Hassan, Q. 2021. Assessing of renewable energy for electrical household ancillary based on photovoltaics and wind turbines. IOP Conference Series: Materials Science and Engineering 1076:1-11.

IRENA. 2023. What are the latest trends in renewable energy? Irena

Junedi, M.M., N.A. Ludin, N.H. Hamid, P.R. Kathleen, J. Hasila and N.A. Ahmad Affandi. 2022. Environmental and economic performance assessment of integrated conventional solar photovoltaic and agrophotovoltaic systems. Renewable and Sustainable Energy Reviews 168:1-12.

Khalid, F., I. Dincer and M.A. Rosen. 2017. Thermoeconomic analysis of a solar-biomass integrated multigeneration system for a community. Applied Thermal Engineering 120: 645-653.

Klöckl, C., S. Wehrle and J. Schmidt. 2023. Low cost, uncertain value: Why cheap PV may still not become UK's main power source. Patterns 4:1-2.

Kose, F., M.H. Aksoy and M. Ozgoren. 2018. Experimental investigation of solar/wind hybrid system for irrigation in Konya, Turkey. Thermal Science 2018:4129-4139.

Kurpaska, S., M. Janowski, M. Gliniak, A. Krakowiak-Bal and U. Ziemiańczyk. 2021. The use of geothermal energy to heating crops under cover: A case study of poland. Energies 14:1-25.

Laaroussi, A., and A. Bouayad. 2019. Study of Economic Impact of Solar Pumping System. Proceedings of 2019 7th International Renewable and Sustainable Energy Conference, IRSEC. pp. 1–4.

Liontakis, A., A. Sintori and I. Tzouramani. 2021. The role of the start-up aid for young farmers in the adoption of innovative agricultural activities: The case of aloe vera. Agriculture (Switzerland) 11:1-24.

Majeed, Y., M.U. Khan, M. Waseem, U. Zahid, F. Mahmood, F. Majeed, M. Sultan, and A. Raza. 2023. Renewable energy as an alternative source for energy management in agriculture. Energy Reports 10:344-359.

Mergoul, K., B. Laarabi, and A. Barhdadi. 2018. Solar water pumping applications in Morocco: State of the art. Proceedings of 2018 6th International Renewable and Sustainable Energy Conference, IRSEC. pp. :1-7.

Mohammed, N.Q., M.S. Ahmed, M.A. Mohammed, O.A. Hammood, H.A.N. Alshara and A.A. Kamil. 2019. Comparative analysis between solar and wind turbine energy sources in iot based on economical and efficiency considerations. Proceedings - 2019 22nd International Conference on Control Systems and Computer Science, CSCS. Pp. 448-452.

Painuly, J.P., and N. Wohlgemuth. 2019. Economics of renewable energy. Routledge Handbook of Energy Economics. Pp. 68-84.

Saputra, M. and H. Umar. 2021. Techno-Economic Analysis for Energy Fulfillment in the University Farm. Lecture Notes in Mechanical Engineering. Pp.113-123.

Seo, S.B., E.S. Go, J.L.J. Ling, and S.H. Lee. 2022. Techno-economic assessment of a solar-assisted biomass gasification process. Renewable Energy 193:23-31.

Sharan, P., K. Kitz, D. Wendt, J. McTigue, and G. Zhu. 2021.

Using concentrating solar power to create a geological thermal energy reservoir for seasonal storage and flexible power plant operation. Journal of Energy Resources Technology, Transactions of the ASME 143:1-15.

Timmons, D. 2017. Renewable energy economics. Building a Climate Resilient Economy and Society: Challenges and Opportunities 196-210.

Villarroel-Schneider, J., S. Balderrama, C. Sánchez, E. Cardozo, A. Malmquist, and A. Martin. 2023. Open-source model applied for techno-economic optimization of a hybrid solar PV biogas-based polygeneration plant: The case of a dairy farmers' association in central Bolivia. Energy Conversion and Management 291:1-18.

Yigezu, Y.A., A. Mugera, T. El-Shater, A. Aw-Hassan, C. Piggin, A. Haddad, Y. Khalil and S. Loss. 2018. Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. Technological Forecasting and Social Change 134:199-206.

Yusupov, Z. 2021. Geothermal power generation. Energy Efficiency and Renewable Energy: Handbook, Second Edition. Pp. 1615-1668.